

of separating the two metals, and also of isolating nickel from other metallic impurities. Further, the discrepancy between the increment values of the author and of Fizeau for these metals is only of the same order as that between the concordant values of the author and of Benoit, 0·46, on the one hand, and of Fizeau, 0·76, on the other, for the 10 per cent. alloy of platinum-iridium, the value for which Fizeau gives in the same table referred to.

Taking, therefore, the values published by Fizeau for the increments of nickel and cobalt as correctly representing the results of his experiments, his values of the coefficients at 0°, the constants a , calculated by use of the increment, are as under:—

$$\left. \begin{array}{l} \text{Nickel} \dots \dots \quad a = 0\cdot000\ 012\ 51 \\ \text{Cobalt} \dots \dots \quad a = 0\cdot000\ 012\ 04 \end{array} \right\} \text{Percentage difference } 3\cdot8.$$

At 100° the coefficients would become—

$$\left. \begin{array}{l} \text{Nickel} \dots \dots \quad a = 0\cdot000\ 013\ 22 \\ \text{Cobalt} \dots \dots \quad a = 0\cdot000\ 012\ 84 \end{array} \right\} \text{Percentage difference } 2\cdot9.$$

The values thus calculated for the expansion at 0° from Fizeau's data are almost identical with the author's values. But the considerable difference between the values and the order of the increments now given and those of Fizeau introduces a different order of progression with rise of temperature. According to Fizeau the difference between the coefficients of the two metals is a diminishing one, the percentage difference having fallen from 3·8 at 0° to 2·9 at 100°; whereas the author's determinations indicate that the difference is an accelerating one, rising from 3·2 per cent. at 0° to 4·3 at 100°.

“On the Waters of the Salt Lake of Urmi.” By R. T. GÜNTHER, M.A., and J. J. MANLEY, Daubeny Curator, Magdalen College. Communicated by Sir JOHN MURRAY, F.R.S. Received June 8,—Read June 15, 1899.

In June, 1897, a portion of the Government Grant was allotted to one of the authors by the Committee of the Royal Society, for the investigation of the fauna and flora of the great salt lake of Urmi, in Persia, as well as of the relations of that fauna and flora to its environment. The present research was undertaken with the view of placing on record some of the conditions prevailing in the lake at the present day.

The extraordinary changes which the level of the waters of the lake has undergone, and is still undergoing, enhance the importance of periodical examinations of the nature of the waters. The advisability of the preservation of such records was urged upon the Royal Society

by its Secretary, 184 years ago. Edmund Halley, in his "Short Account of the Cause of the Saltiness of the Ocean, and of the several Lakes that emit no Rivers," expressed himself as follows:—"I recommend it therefore to the *Society*, as opportunity shall offer, to procure the Experiments to be made of the present degree of Saltiness of the Ocean, and of as many of these Lakes as can be come at, that they may stand upon Record for the benefit of future Ages."* At the present day there are additional reasons for recording the properties and composition of such salt lakes as are known to be inhabited by life, because Schmankewitsch† and many others of the modern school of *Entwickelungsmechanik* (Morgan, Loeb, Vernon, &c.) have proved that every change in the salinity of the waters is accompanied by definite, rapid, and corresponding changes in the anatomical structure of certain of their halophilous fauna, and especially of the species of *Artemia*, one of which occurs in Lake Urmi.‡

The superficial area covered by Lake Urmi is about 1750 square miles, or about four times that of the Dead Sea. For so large an expanse of water its depth is inconsiderable; the greatest soundings do not exceed 40 feet, and since much of the lake is extremely shallow, its average depth is probably under 20 feet. When viewed from the commanding heights of one of its islands, its waters show that brilliant deep blue colour which is so characteristic of salt lakes, but as seen from a boat, the light which is reflected from the light grey mud at the bottom is green.

The temperature of so small a volume of water, which is at the same time so extended as Lake Urmi, must necessarily vary considerably with the seasonal changes of temperature. During the months of July and August the temperature of the surface waters varied from 27.8° C. to 25.8° C., and the temperature of the bottom water at a depth of about 25 feet was 25° C. The specific gravity of the water, as measured on the spot by an ordinary hydrometer, was 1.11, whether the water was drawn from near the bottom or from the surface of the lake; it may therefore be assumed that the waters of the lake remote from the mouths of the fresh water tributaries were of a fairly uniform density, a result which was probably due to the thorough mixing of the waters produced by the strong south-easterly breezes prevalent at the time.

The total quantity of water available for the more detailed examination was brought home in two glass wine bottles, holding about $\frac{3}{4}$ litre a-piece. The samples A and B were collected on September 16, 1898, near the base of the Bezau Daghi, on the western shore of the lake, where there is comparatively deep and clear water close in shore. The bottles were carefully corked, and it is, I think, fair to assume that no

* 'Phil. Trans.,' vol. 29, p. 299, 1715.

† 'Zeitschrift Wiss. Zoologie,' vol. 25, 1875.

‡ Günther, 'Nature,' vol. 53, p. 435.

great changes have occurred in the interval between the bottling of the samples in Persia and their examination in Magdalen College Laboratory, in Oxford, seeing that the discrepancies between the analyses are very small.

The examination was both physical and chemical.

PHYSICAL EXAMINATION.

Determination of Specific Gravity.

The specific gravities of the two samples of water (A and B) were determined by Mr. H. N. Dickson, according to the method of Sprengel, with the following mean results :—

	A.	B.
Specific gravity, at 15° C.	1.11338	1.11389
„ „ 0.3° C.	1.11891	1.11945
Difference.....	0.00553	0.00556

Determination of Refractive Index.

The refractive indices (μ) were determined by means of a hollow quartz prism of 60° 6' refracting angle, and a large spectrometer* reading to 2" of arc. The water was at a temperature of 12.2° C. during the readings.

	A.	B.
Angle of minimum deviation of D line.....	25° 50' 4"	25° 50' 35",
whence $\mu = 1.36110$	1.36122	

It is believed that similar optical measurements will be found to be applicable to ordinary sea waters and will be found to give a more accurate and a more readily obtained indication of the physical nature of the water than the ordinary specific gravity methods.

Determination of Boiling Point.

It has long been customary to record the boiling points of strongly saline natural waters, but in only too many cases, owing to the lack of description of the conditions of the experiment, the records have only a small value. Many trials have convinced us that the boiling points of brines properly determined under similar conditions yield as reliable, although less minute, information concerning the degree of salinity as specific gravity determinations.

The salt water was boiled in a platinum bottle, to which an inverted condenser containing ice-cold water was attached, in order to prevent

* The spectrometer, which was constructed for Dr. Bedson, and the prism employed are the property of the Royal Society.

loss of water vapour and consequent concentration. The temperature was measured by a form of platinum resistance thermometer, which reads to $0\cdot01^{\circ}\text{C}$. Three readings were always taken. Firstly, the temperature of the steam from ordinary boiling water in a steam jacket and under atmospheric pressure; secondly, the temperature of the boiling salt water; and finally, the temperature of steam once more. If the first and last readings were identical, it was considered that the conditions of the experiment had remained constant. As a matter of practice it was found that when once the boiling point of the salt water had been reached, the water continued to boil at that temperature for any length of time, so long as the pressure remained constant.

	A.	B.
Boiling point under normal pressure	$103\cdot84^{\circ}\text{ C.}$	$103\cdot88^{\circ}\text{ C.}$

It will thus be seen that the three results of the physical examination of the two samples A and B are all mutually confirmatory, in so far that they indicate that sample B had become a little more concentrated than A during its journey from Persia to Oxford.

CHEMICAL EXAMINATION.

The method adopted was that of Dittmar, as described in the Report on the Composition of Ocean Water.*

For the estimation of the lime and magnesia, 20 c.c. of the water, weighing approximately 22.2 grams, were measured off, and the quantities used in the determination of the potash and total salts were half that amount.

Examination of the Correctness of Dittmar's Factor 0.91 for "Crude" Lime.

Forty c.c. of the water were measured off and weighed. In accordance with Dittmar's recommendation, the calcium was precipitated as oxalate, filtered, washed, and finally weighed as oxide. The "crude" oxide obtained amounted to 0.0319 gram: this was then redissolved and again precipitated and weighed as "pure" oxide; the weight was found to be 0.0284 gram. If we multiply the weight of crude lime, 0.0319 gram, by Dittmar's factor 0.91, we obtain 0.0290 gram as the weight of "pure" lime. This amount only differs from that actually found by +0.0006 gram, thus affording confirmatory evidence of the correctness of the factor.

The quantities of pure lime given below were determined by reprecipitation and repurification. The magnesia was precipitated by

* 'Challenger Reports,' "Physics and Chemistry," vol. 1.

sodium phosphate instead of by ammonium phosphate as Dittmar recommends, because when the latter reagent was used the magnesia was found to come down very slowly and to adhere inconveniently to the sides of the vessel.

The soda was determined by the method in which all the bases are converted into normal sulphates, and the weight of the mixed sulphates is diminished by the subtraction of the weights of the potassium, calcium, and magnesium sulphates. The potash was determined by precipitation from the mixed sulphates by chloride of platinum, according to Dittmar's third and final method,* and his observations upon the appreciable solubility of the finely divided platinum by the cold dilute hydrochloric acid employed for washing were confirmed.

From the known amounts of lime, magnesia, and potash (see below) were deduced the following weights of normal sulphates in 100 grams of the mixed sulphates:—

	A. Grams.	B. Grams.
Potassium sulphate	0·258	0·259
Calcium sulphate	0·146	0·171
Magnesium sulphate	1·870	1·871
Sodium sulphate (by difference) ...	15·547	15·606
 Total sulphates	17·821	17·907

The quantities of the principal saline components dissolved in 100 grams of the water of Lake Urmia are—

	A.	B.
Lime (CaO)	0·0603	0·0706
Magnesia (MgO)	0·6265	0·6266
Potash (K ₂ O).....	0·1394	0·1402
Soda (Na ₂ O)	6·788	6·814
Chlorine (Cl)	8·496	8·536
Sulphates (SO ₃)	0·6205	0·6312
 16·7307	16·8186	
Oxygen equivalents of the chlorine to be deducted	1·9167	1·9258
 Total salts in 100 grams of water	14·814	14·893

* 'Challenger Reports,' *loc. cit.*, p. 16.

Or, recalculated for 100 parts by weight of total salts, we have—

	A.	B.
Chlorine (Cl)	57.351	57.315
Sulphates (SO ₃)	4.189	4.238
Lime (CaO)	0.407	0.474
Magnesia (MgO)	4.229	4.207
Potash (K ₂ O)	0.941	0.941
Soda (Na ₂ O)	45.822	45.753
Deduct [O] per [Cl ₂]	12.939	12.931
	100.000	99.997

The hypothetical proximate composition of 100 parts of the total salts was calculated, with the following results :—

	A.		B.
		i.	ii.
Sodium chloride	86.332	86.203	86.203
Magnesium chloride	6.661	6.816	6.816
,, sulphate	4.211	4.150	3.915
Calcium sulphate	0.988	1.151	1.151
Potassium sulphate	1.741	1.741	1.741
	99.933	100.061	99.826

Result B i was obtained by calculating the magnesium sulphate from the residual sulphate (SO₃). Result B ii from the residual magnesium.

It is a remarkable fact that notwithstanding the occurrence of limestone rocks and pebble beaches in the lake, no combined carbonic acid could be detected in the water ; indeed, there would be no base for it to combine with. On the other hand, small quantities of free carbon dioxide were present dissolved in the water, and were estimated by Tornöe's method.*

	A.	B.
Free carbon dioxide in solution...	0.028 per cent.	0.017 per cent.

Result A was the mean of two determinations which agreed to within 0.002 per cent., and result B was obtained twice by the use of different standard solutions ; the results were identical.

* Before applying Tornöe's method for the estimation of carbon dioxide to the samples of water A and B, two determinations of combined carbon dioxide in a dilute and standard solution of sodium carbonate were carried out, in order to ascertain the degree of accuracy one might hope for. In the first, the carbon dioxide found only exceeded that known to be present by 0.0003 gram, and in the second by 0.0001 gram.

No iodine or bromine could be detected in the small quantity of water available for examination.

Spectroscopic examination revealed the presence of a trace of barium. The quantity present would have been quite unweighable, and although estimated with the calcium could not have vitiated the results.

The results given under the heading B are regarded as those which most nearly represent the true condition of the lake, and consequently no attempt has been made to strike an average between the two series of results. The A results are given in extenso in order to demonstrate the degree of reliability of the B results, a matter which will be of importance in the future, when, after an interval of some years, another investigation of the water of Lake Urmī is made.

“On the Application of Fourier’s Double Integrals to Optical Problems.” By CHARLES GODFREY, B.A., Scholar of Trinity College, Isaac Newton Student in the University of Cambridge. Communicated by Professor J. J. THOMSON, F.R.S. Received June 12,—Read June 15, 1899.

(Abstract.)

The propagation of plane plane-polarised light in the direction of z is governed by the equation $V^2 \frac{\partial^2 \phi}{\partial z^2} = \frac{\partial^2 \phi}{\partial t^2}$, where V is the velocity of light.

The most simple solution of this equation is—

$$\phi = R \cos \left[u \left(t \pm \frac{z}{V} \right) + \psi \right] \dots \dots \dots \quad (1).$$

This may be interpreted as a train of waves of amplitude R , period $2\pi/u$, and phase ψ , travelling with velocity V . This train of waves is without beginning or end. Most of the results of physical optics have direct application to a disturbance of the above form.

No radiation is found in nature which has the properties of the above function. The fact alone that all natural radiations have beginning and end would suffice to render (1) an inadequate representation.

It is required to solve the problem how to represent any natural radiation faithfully without losing the conveniences connected with the form (1). The problem recalls the familiar process of harmonic analysis. This process is applicable only to periodic functions, whereas such a motion of the æther as constitutes white light is non-periodic. In this connection it has been pointed out by Gouy